COMPARATIVE SURVIVAL AND GROWTH OF F_1 WILD AND F_3 GENERATIONS OF THE SAME STRAIN OF HATCHERY-REARED BROOK TROUT *(SALVELINUS FONTINALIS)* PLANTED IN TWO SMALL LAKES

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J.M. Fraser

Ontario Ministry of Natural Resources
Maple, Ontario L0J 1E0

and

C. Rumsey

Sir Sanford Fleming College, School of Natural Resources
Lindsay, Ontario K9V 5E6

C.H. Olver, Editor

Ontario Ministry of Natural Resources

Vincent G. Kerrio
Minister

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Survival and growth of hatchery-reared first generation (F_1 wild) brook trout (*Salvelinus fontinalis*), progeny of wild Dickson Lake parents, were compared with the third hatchery-spawned and reared generation (F_3) of the same strain by recaptures of matched plantings of fall fingerlings stocked in two study lakes in 1981, 1982 and 1983. In one lake in which there was minimal competition from resident fish species, the matched plantings were recovered in equal proportion. In the lake which supported a resident brook trout population, survival of the F_3 plantings was significantly lower than that of the F_1 wild plantings. The poorer performance of the F_3 fish could not be attributed to genetic changes nor to differential conditioning by the hatchery environment. It is possible, however, that embryonic development of the F_3 fish differed from that of the F_1 fish owing to a potential difference in composition of the egg yolk. Female parents of the F_1 wild fish ate natural foods in the lake, whereas parents of F_3 fish were maintained on an artificial diet. There were no essential differences in growth between F_1 wild and F_3 fish in either study lake. In one study lake, a drastic decrease in survival of the final (1983) matched plantings was probably due to predation by a pair of loons that nested (successfully) on the lake in 1984 and 1985.

Key words: domestication, matched plantings, competition, loon predation

INTRODUCTION

Brook trout (*Salvelinus fontinalis*) strains that have been domesticated over many generations have exhibited poor survival when released in the wild (Greene 1952; Vincent 1960; Flick and Webster 1964; Fraser 1981). Some changes in fish stocks could also be due to short-term domestication. Reisenbichler and McIntyre (1977), for example, reported genetic differences in growth rate and survival between offspring of wild steelhead (*Salmo gairdneri*) and hatchery fish that were not more than two generations removed from wild stocks. Ryman and Stahl (1980) found that drastic genetic changes in brown trout (*Salmo trutta*) had been induced within 1-2 generations of fish cultural procedures. To explore the possible effects of short-term domestication on brook trout, this study compares the survival and growth in the wild of matched plantings of first generation (hatchery-reared) wild stock of brook trout and the third hatchery-reared and spawned generation of the same stock.

METHODS

The wild stock of brook trout used in this study is native to Dickson Lake (45° 47'N, 78°13'W), Algonquin Park, Ontario. The stock is fast growing, shoal spawning and relatively long-lived (Fraser 1985). In the fall of 1980, 1981 and 1982, 12-15 fish of each sex were mated on an approximate 1:1 basis. The fertilized eggs were transferred to hatchery facilities at Sir Sandford Fleming College, Lindsay, Ontario, where the eggs were incubated and hatched and the fry were reared to the fall fingerling stage. Following the terminology suggested by Moyle (1969), these progeny were termed the "F_1 wild" generation. These fish were reared in tanks adjacent to similar tanks containing the third generation (F_3) fish of the Dickson Lake strain.

The F_3 fish were descendent from Dickson Lake brook trout first transported as fertilized eggs (from 12-15 matings) to the college hatchery in 1974. In 1977, an F_2 generation was produced by random

mating of a minimum of six F_1 wild females and six F_1 wild males. The F_3 generations were produced from random matings using at least 15 F_2 females and fertilizing the eggs of each female with sperm from two F_2 males.

Feeding and care of the fish followed current fish cultural practices and care was taken to ensure that the experimental lots of F_1 wild and F_3 received the same treatment. Prior to fall planting, mean weights of the two generations were determined by counting the number of fish in a 1 kg lot. Fall fingerlings were anaesthetized with ethyl *m*-aminobenzoate methanesulfonate (MS222), fin-clipped (F_1 wild-right ventral; F_3 - left ventral) and counted into two lots of 1000 fish each of F_1 wild and F_3. The fingerlings were transported by truck (2.5-3 hr) in cool, oxygenated tanks to the portage access to the two study lakes (Shallnot, Little Minnow). The fish were then transferred to plastic bags containing water and oxygen under pressure (Fraser 1976), carried in packsacks (20 min) and released at the shore of the lakes. In this manner, matched plantings of F_1 wild and F_3 brook trout were made in both Shallnot Lake and Little Minnow Lake in September of 1981, 1982 and 1983.

The two study lakes, located less than 22 km from Dickson Lake, are similar in area (9 ha) and depth (max. 9 and 13 m), are slightly acidic (pH 6.2-6.4) and relatively infertile (TDS 32-44 mg L^{-1}). The fish community in Shallnot Lake consists of a naturalized population of brook trout and three cyprinid species. The naturalized population is the result of assortative mating of planted Dickson Lake, Lake Nipigon and Hills Lake domestic brook trout strains during the 1970s. Little Minnow Lake contains brook stickleback (*Culaea inconstans*), the only fish species to survive a treatment with a fish toxicant (rotenone) in 1980.

The study lakes were sampled annually by angling and/or gillnetting, beginning in 1982. Shallnot Lake, a fish sanctuary closed to angling, was fished with gill nets (875 m yr^{-1}) set overnight. The gillnet gang was made up of 1.8 m x 16.2 m panels of 51-, 64- and 76 mm (stretched measure) monofilament nylon. Planted trout were recovered from Little Minnow Lake by angling in the spring and early summer, and by gill nets (583 m annually) in late summer after angling had subsided. Anglers returning from Little Minnow Lake must pass a creel survey station where approximately 75% were interviewed and their catches examined. The angling data have, therefore, been multiplied by a factor of 4/3 to provide estimates of total angling returns.

All fish caught in the gill nets were brought to the laboratory for examination (fin clip, fork length, weight, sex). Stomach contents of a subsample of the catch were preserved and later identified, separated into taxonomic groups, and the weight of each group taken to the nearest 0.1 g. Group weights (pooled) were expressed as percentages of the total weight of food examined. Percentage frequency of occurrence of the various food items was also calculated. The coefficient of condition (K) was computed: $K = W \times 10^5/L^3$, where W is the weight in grams and L is the fork length in millimetres. Mean lengths of the two generations at various ages were compared by the "Student's" t-test (Snedecor 1957).

RESULTS

COMPARATIVE RECOVERIES

The 1981 and 1982 plantings of F_1 wild brook trout were recovered from Shallnot Lake in significantly greater numbers than the matched plantings of F_3 fish (1981, chi-square 4.299, $p = 0.05$, 1 df; 1982, chi-square 10.322, $p = 0.05$, 1 df). The recovery of F_1 wild from the 1981 plantings was 7.7% compared to 5.4% for the F_3 fish; and, from the 1982 plantings, 15.2% of the F_1 wild were recovered compared to 10.4% of the F_3 fish (Table

1). Recoveries from the 1983 plantings were low (<3%) for both generations of planted fish. The annual gillnet catch of resident brook trout fluctuated between 65 and 283 fish during 1982-1986 (Table 1).

There was no significant difference (chi-square test) in the percentage recoveries of planted F_1 wild and F_3 fish in Little Minnow Lake. Anglers and later experimental gill nets, caught about 18% of each generation planted in 1981 and about 15% of each generation planted in 1982 (Table 2). Recoveries from the 1983 plantings in Little Minnow Lake were low, but similar (7-8%).

GROWTH AND CONDITION

Generations of F_1 wild and F_3 fish planted in the same lake grew at similar rates. In Shallnot Lake, both lots of the 1981 planting reached 33.7 cm in length at age 2+ and were 38.9 and 38.3 cm long, respectively, at age 3+ (Table 3). Both lots of the 1982 planting also grew at the same rate, but the rate was slower than that of the 1981 planting. This trend continued, and the 1983 plantings grew at a slightly slower rate than the 1982 plantings. Growth of both generations of brook trout was similar, but more rapid in Little Minnow Lake, where brook stickleback was the only other fish species.

Table 1. Recovery by gillnetting of matched plantings of fall fingerling F_1 wild and F_3 generations of Dickson Lake brook trout strain from Shallnot Lake, 1982-86.

	Year of planting						
	1981		1982		1983		
Planted lot	F_1 wild	F_3	F_1 wild	F_3	F_1 wild	F_3	Resident brook trout
Fin clip	RV	LV	RV	LV	RV	LV	
Numbers planted	1000	1000	1000	1000	1000	1000	
Mean weight (g)	11.5	13.1	5.1	6.5	8.5	8.5	
Total weight planted (kg)	11.5	13.1	5.1	6.5	8.5	8.5	
Number caught in 1982	30	24					152
1983	40	25	36	27			65
1984	7	5	107	70	7	6	88
1985			9	7	18	17	130
1986					1	1	283
Total	77	54	152	104	26	24	
% recovered	7.7	5.4	15.2	10.4	2.6	2.4	
Weight (kg) caught in 1982	2.9	3.3					58.2
1983	19.1	11.4	4.7	3.5			23.1
1984	5.2	3.6	37.6	26.0	0.5	0.5	33.2
1985			5.3	5.1	6.4	6.3	31.7
1986					0.6	0.7	77.5
Total	27.2	18.3	47.6	34.6	7.5	7.5	
Weight recovered / Weight planted	2.4	1.4	9.3	5.3	0.9	0.9	

Table 2. Recovery by angling/gillnetting of matched plantings of fall fingerling F_1 wild and F_3 generations of Dickson Lake brook trout strain from Little Minnow Lake, 1982-85.

	Year of planting					
	1981		1982		1983	
Planted lot	F_1 wild	F_3	F_1 wild	F_3	F_1 wild	F_3
Fin clip	RV	LV	RV	LV	RV	LV
Numbers planted	1000	1000	1000	1000	1000	1000
Mean weight (g)	11.5	13.1	5.1	6.5	8.5	8.5
Total weight planted (kg)	11.5	13.1	5.1	6.5	8.5	8.5
Numbers caught in 1982	20/82[a]	36/85				
1983	72/9	59/5	23/66	10/75		
1984			55/12	52/7	11/28	17/31
1985			1/0	2/0	25/1	27/6
Total	183	185	157	146	65	81
% recovered	18.3	18.5	15.7	14.6	6.5	8.1
Weight (kg) caught in 1982	12.8	15.7				
1983	35.1	27.3	11.0	11.5		
1984			25.4	22.7	4.8	5.4
1985			1.0	2.1	9.2	11.3
Total	47.9	43.0	37.4	36.3	14.0	16.7
Weight recovered / Weight planted	4.2	3.3	7.3	5.6	1.6	2.0

[a]Creel/nets.

Coefficients of condition computed for the two generations at various ages are summarized in Table 4. In both lakes, the F_3 generation exhibited a slightly higher coefficient than the F_1 wild fish in the majority of comparisons. There was little difference in the coefficient between lakes.

FOOD HABITS

F_1 wild and F_3 brook trout planted in Shallnot Lake both ate the same food organisms that resident brook trout utilized. For example, in June 1984, all three groups fed heavily on Odonata nymphs and Coleoptera larvae, and these forms made up over 80% of the diet (Fig. 1). In Little Minnow Lake, both groups of planted trout ate mainly stickleback, Odonata and, to a lesser extent, leeches and various aquatic insect larvae (Fig. 2). The dominance of the brook stickleback in the diet reflects the abundance of this species in the lake.

DISCUSSION

The results of the comparative tests were different in the two study lakes. In Shallnot Lake, recovery of the F_1 wild plantings was significantly higher than that of the F_3 plantings in two comparisons. In contrast, there was no significant difference in percentage recovery of the F_1 wild and F_3 plantings from Little

Table 3. Mean length (cm) of F_1 wild and F_3 generations of Dickson Lake brook trout strain at various ages following planting as fall fingerlings in Shallnot and Little Minnow lakes. Means were calculated from gillnet samples collected in late June, 1982-85, from Shallnot Lake, and in late July-early August, 1982-85, from Little Minnow Lake.

	Year of planting											
	1981				1982				1983			
	F_1 wild	N[a]	F_3	N	F_1 wild	N	F_3	N	F_1 wild	N	F_3	N
SHALLNOT LAKE												
Length (cm)												
at age 1+	20.5	30	21.0	24	21.1	36	21.9	27	18.4	7	18.3	6
2+	33.7	40	33.7	25	31.1	98	31.2	70	30.4	18	31.1	17
3+	38.9	7	38.3	5	36.8[b]	9	38.5[b]	7				
LITTLE MINNOW LAKE												
Length (cm)												
at age 1+	21.3	82	21.6	85	21.3	66	21.7	75	21.3	31	21.8	28
2+	35.7	9	35.3	5	34.6	12	36.1	7	31.1[c]	10	31.1[c]	9
3+			39.7	1	42.1	1	43.4	2				

[a]N = number of fish.
[b]Significant difference between these lengths; t = 2.5259, 14 df, p = 0.05. Other differences non-significant.
[c]Mean was based on spring creel catches.

Minnow Lake. The two study lakes, however, differed in one key respect. Unlike Little Minnow Lake, Shallnot Lake supported a naturalized brook trout population that competed with and probably preyed upon the planted fish. In this situation, the F_1 wild generation survived at a higher rate than the F_3 generation. In Little Minnow Lake, however, only brook stickleback were extant and, in this less competitive environment, both planted generations survived at a similar rate.

We do not know why the F_1 wild and F_3 generations survived at different rates following planting in Shallnot Lake. It was not likely due to genetic differences because the difference between the F_1's and F_3's was only .024-.008 = .016 or 1.6% inbreeding. The environmental effects of fish culture are also ruled out as a pos-

Table 4. Mean coefficient of condition (K) of planted F_1 wild and F_3 Dickson Lake brook trout strain at various ages in Shallnot and Little Minnow lakes. See Table 3 for numbers of fish.

	Year of planting					
	1981		1982		1983	
	F_1 wild	F_3	F_1 wild	F_3	F_1 wild	F_3
SHALLNOT LAKE						
age 1+	1.27	1.27	1.25	1.29	1.36	1.38
2+	1.24	1.30	1.18	1.24	1.25	1.30
3+	1.14	1.24	1.24	1.32		
LITTLE MINNOW LAKE						
age 1+	1.23	1.26	1.27	1.32	1.32	1.30
2+	1.28	1.29	1.25	1.33	1.22	1.25

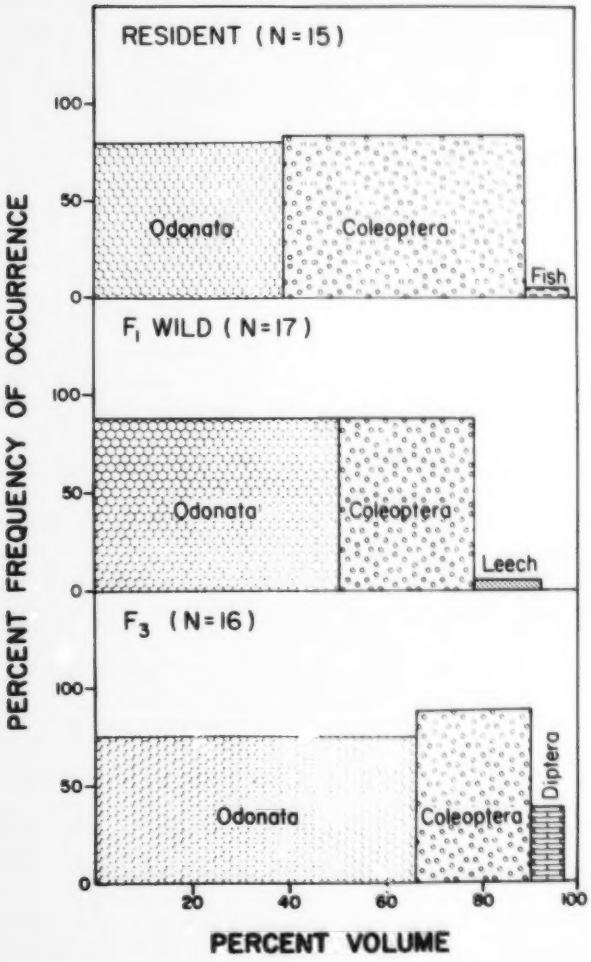

Fig. 1. The food of resident brook trout (top); planted F_1 wild Dickson Lake strain (middle); and planted F_3 Dickson Lake strain brook trout (bottom) caught in Shallnot Lake, June 1984.

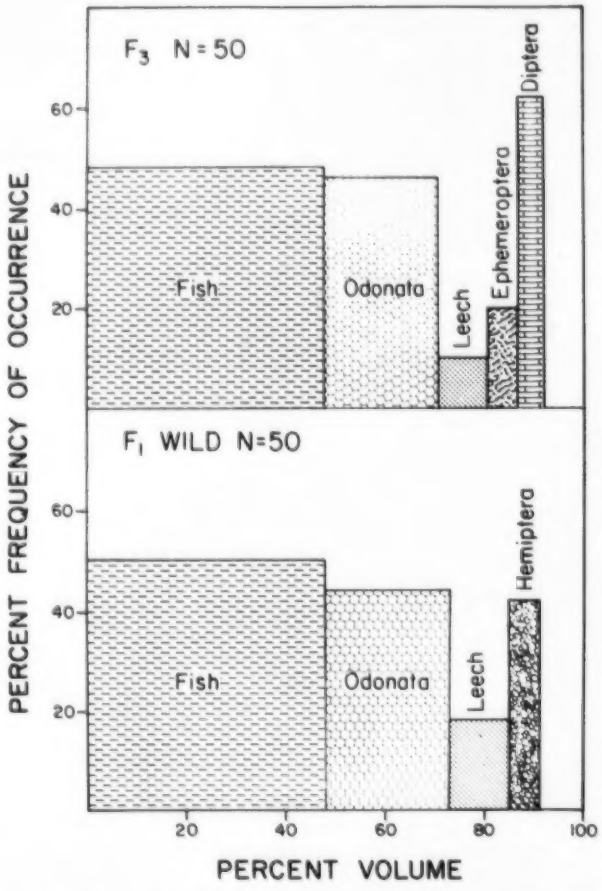

Fig. 2. The food of planted F_3 (top) and F_1 wild (bottom) Dickson Lake brook trout strain caught in Little Minnow Lake, August 1982.

sible factor because both lots of fish received identical treatment during incubation, rearing and planting. It is possible, however, that the difference in survival between the lots may be due to a maternal influence acting through the egg yolk (P. Ihssen, Ontario Ministry of Natural Resources (OMNR), Box 50, Maple, Ontario L0J 1E0, pers. comm.). The F_1 wild trout hatched from eggs of females feeding on natural foods in the lake, whereas the F_3 fish were progeny of females maintained on an artificial diet. The difference in the diet of the parents (female) of the two generations being compared could be especially important if one diet, natural or artificial, was (say) nutritionally deficient or contained contaminants. An extreme example of the latter case was the accumulation of DDT in lake trout (*Salvelinus namaycush*) of Lake George, New York, that caused a complete loss of fry from eggs taken from these fish (Burdick et al. 1964). Normal survival

occurred, however, when male lake trout from Lake George were crossed with females from other lakes. Flick and Webster (1964) recognized the diet problem in rearing wild stocks in the hatchery for comparative studies with domestic trout. They stated, "There is a problem inextricably tied to any test using hatchery fish *per se*: the nutritional endowment of the domestic eggs and fry presumably reflects the artificial diet of the brood stock and this factor may be of importance in determining later performance".

Other studies suggest that factors in addition to the nutritional endowment of the eggs may be involved. Goldberg et al. (1969), in their biochemical studies involving the measurement of lactate dehydrogenase in reciprocal hybrids of trout during development, noted that a maternal influence was at play in the regulation of enzyme levels. Since the maternal influence persisted until after yolk sac absorption, they suggested that some cytoplasmic component which acts as a regulator of gene output is stored in the yolk. In his studies of inheritance of thermal resistance in *Salvelinus* hybrids, Ihssen (1973) hypothesized that cytoplasmic and/or nuclear modifiers associated with the lake trout female may affect the phenotypic expression of genotypes derived from the F_1 of lake trout maternal origin. Dentry and Lindsey (1978) showed that vertebral variation in zebrafish (*Brachydanio rerio*) was related to the prefertilization temperature history of their parents. Swain and Lindsey (1985), experimenting with the cyprinodant fish *Rivulus marmoratus*, presented evidence that environmental influences acting on the parents before conception of their offspring were a source of meristic variation. They suggested that nonmeristic characters of offspring, such as early survival, growth rates and fecundity, are probably also subject to nongenetic prefertilization influences. Thus, the possibility that environmental influences acting on parents prior to the production of offspring may substantially affect the survival of offspring, is one that must be considered in future studies of domestication effects.

Although the results of this study are inconclusive, it is evident that the survival capability of the F_3 generation of Dickson Lake brook trout was somehow reduced during two generations of domestication. Various attributes of "wildness", such as wariness, may be reduced in these fish to such an extent that they are at a competitive disadvantage compared to F_1's in the presence of a resident salmonid population, as in Shallnot Lake. The greater recovery of both F_1 and F_3 fish of the 1981 and 1982 plantings in Little Minnow Lake demonstrates the influence of resident fish species on survival of planted fish (Fraser 1972, 1978).

It is noteworthy that growth of both generations in Shallnot Lake slowed from the first to the last (1983) planting, something that managers should expect with annual planting regimes. The decrease in growth of the 1983 planting in Shallnot Lake was probably due to increased survival of the 1982 planting, combined with an increase in the lake-born brook trout population in 1984. Also, the similar growth rate of both F_1's and F_3's in Shallnot Lake, and between Shallnot and Little Minnow lakes, demonstrates that the presence of the naturalized population of brook trout had no disproportionate effect on growth rate both within and between lakes.

Survival of the first two matched plantings in Little Minnow Lake was similar and relatively high. This level of recovery was due, to some extent, to the combined effort of angling and gillnetting. However, similar effort in 1984 and 1985 recovered a much smaller proportion of the 1983 planting. The probable cause of the poor survival of the 1983 plantings was predation by the common loon (*Gavia immer*). During the course of various studies, beginning in 1961, loons had been observed to forage occasionally

on Little Minnow Lake. In 1984 and 1985, however, a pair nested successfully and raised one young each year. The resultant intensified feeding on fish in the lake in those years undoubtedly decreased survival of the 1983 matched plantings. Barr (1973) has shown the common loon to be an effective predator of planted trout in small reclaimed lakes. Observations on loon activities in Algonquin Park (Fraser, unpubl.) and those of Flick (1983) in Adirondack mountain lakes confirm Barr's observations.

The experiences of this study demonstrate two natural processes that govern the degree of survival of planted fish. Competition was the dominant factor in Shallnot Lake; predation predominated in Little Minnow Lake. There is also the suggestion that even short-term domestication may reduce a stock's capability to compete with resident fish species in the wild.

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